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XV.—*Description of a new Species of Crinoids with Articulating Spines.* By GEORGE JENNINGS HINDE, Ph.D., F.G.S.

[Plate VI.]

IN the 'Proceedings of the American Philosophical Society' for 1883 Prof. Henry S. Williams described a crinoid with movable spines under the generic and specific term of *Arthroacantha ithacensis*. The forms described were merely impressions of the organism in fine sandy shales, the objects themselves having been dissolved away; but, according to Prof. Williams, the impressions were so perfect that the minutest structural details could be readily ascertained. Notwithstanding this circumstance, some little doubt was felt whether these spines might not have been of a similar character to those which in many other Palæocrinoids project from the surface of their plates, and are but solid continuous extensions of the plates themselves, and with them are immovably fixed in the body-wall of the crinoid. The specimens in my possession, however, which I now propose to describe, conclusively show that Prof. Williams had correctly interpreted the impressions and casts of the spines and plates in the Devonian shales, and that, however novel the feature of movable spines

may be in the history of the Crinoidea, no doubt can be entertained of the fact.

My specimens, consisting of eleven more or less perfect bodies and numerous fragments of stems, are from calcareous shales of Middle Devonian age at Arkona, Province Ontario, Canada. They were collected by myself between 1875 and 1878, and though fully conscious of the remarkable character of the articulating spines which they possessed, other investigations prevented me from describing them till now; and it is only since beginning to work at them quite recently that I became aware that Prof. Williams had already described a form with similar spines from a higher geological horizon in the Devonian series at Ithaca, in the State of New York.

Though the specimens are somewhat crushed and distorted, so that no single individual exhibits all the characters, yet they possess the distinct advantage over those described by Prof. Williams in that the objects themselves, and not merely their casts, are present; and by collating the different specimens I have been enabled to ascertain that, while there can be no doubt that they possess the same essential features as the type of the genus, they yet vary sufficiently, in many important features, to constitute a distinct species. The characters shown in these specimens make it necessary to extend and modify Prof. Williams's description of the genus based on the casts of *A. ithacensis*.

Before referring to these, however, I may state that the name *Arthracanthus* was employed by Schmarda * in 1854 for a genus of Rotatoria. The term *Arthroacantha*, applied by Williams to this genus of crinoids, is derived from the same Greek words, and is essentially similar to Schmarda's, though less correctly rendered. I consulted independently two eminent scientific authorities who are specially familiar with questions of nomenclature, and they agreed that the term later employed was invalid, from its resemblance to that previously used by Schmarda, and I propose therefore to substitute in its place the term *Hystricrinus* †. As it will be necessary to make reference to the new species described below, I may here apply to it the name of *Hystricrinus Carpenteri*, in honour of my friend Dr. P. Herbert Carpenter, M.A.

HYSTRICRINUS = *Arthroacantha*, Williams, emend.

*Generic characters.*—Body of crinoid inversely conical or

* Denkschr. k. k. Akad. d. Wiss. Wien, vol. vii. 1854, p. 22.

† Ὕστριξ, a porcupine.

cup-shaped, with distinct bilateral symmetry. The surface covered irregularly with minute tubercles, to which were articulated delicate spines, similar to those of an *Echinus*.

The base of the calyx is open cup-shaped, consisting of three equal or subequal plates, which, at their margins, form a six-sided figure. There are three series or zones of radials ($3 \times 5$). The first or true radials ($R^1$) are large, subequal, flattened, quadrangular plates, and, like a spade, are wider at their summits than at their bases. Their distal margins are either straight or slightly elevated towards the centre, which is considerably thicker than the rest of the plate and has a semicircular excavation, with a finely ridged facet for the reception of the second radial. This so-called second radial ($R^2$), the first brachial (br.$^1$) of Zittel, is a short four-sided joint or plate, which reaches very little above the margin of the first radial, in which it is inserted. The third radial ($R^3$) or axillary, the br.$^2$ of Zittel, is pentagonal, and either shorter or longer than the second. On each of the facets of its upper surface it bears an arm (*ar*), so that there are ten arms altogether. The plates or joints of the lower portion of the arms are in a single vertical series, whilst higher the joints are wedge-shaped and disposed alternately in a double series. The pinnules (*pi*) consist of five or more joints each. A single interaxillary plate (*int*) is present between the lower arm-joints.

A large anal plate (*A*), nearly resembling in outline the first radials, but narrower at the distal margin, is inserted on the posterior side of the body between the two first radials. Its summit is on a level with that of the radials. The anal interradial area, or the space immediately above the anal plate and between the second and third radials and the lower arm-joints on either side, is occupied by three vertical zones of small plates, with six or seven plates in each zone (*Ib.A*). The anal aperture is not shown in any of the specimens yet discovered.

In each of the other areas bounded by the distal margins of the first radials below, the second and third radials and the lower arm-joints on either side, and the true plates of the vault above, there are three vertical zones of plates with three, and occasionally four, plates in each zone (*Ib*). The middle plate of the lower zone is clearly larger than the rest. These plates are distinctly interradial in position, and might be termed interradial plates; but as their lateral margins connect only with the second and third radials (which are merely radials in a conventional sense) and with the lower arm-joints, I prefer to follow Zittel in designating them interbrachial plates. Both these and the anal interradial plates are of the same character as the primary radials and basals of the calyx,

and quite distinct from the vault-plates with which they connect above, and they enclose and unite together the second and third radials and the lower arm-joints into one solid immovable cup with the lower radials and basals.

The vault is depressed, convex, and is formed of a peripheral b order of numerous minute relatively thick plates, and a central portion of larger plates covered with sinuous grooves and tubercles.

The column or stem is cylindrical, with alternately larger and smaller joints. The rim of the larger joints is extended into a sharp-edged flange. At irregular intervals there are nodes, each bearing a whorl of five cirri. The central canal of the stem is cylindrical and moderately large.

The main differences between the characters assigned to the genus by Prof. Williams and those above given consist in the number and position of the interbrachial plates, the absence of a series of smooth radiating plates in the vault, and the nodal cirri of the stem.

Prof. Williams does not directly mention interradial or interbrachial plates, but states * merely that "along the upper rim of the calyx is a row of small plates which lack the tubercles," without further particulars as to their number. In the fig. 1 of the plate accompanying his paper four of these plates are shown in one interbrachial area, and but three in another, and the plates of the vault apparently connect with their upper margins. Nothing is stated or shown in the figure of the plates above the anal plate. I am of course unable to determine whether this notable difference in the number of the interbrachial plates in *H. Carpenteri* and *H. ithacensis* arises from the imperfect condition of preservation of this latter species or is really existent; but I should think it probable that the vault-plates in Prof. Williams's specimens have been pressed down over the higher zones of the interbrachial plates, and thus concealed them from observation.

With regard to the radiating rows of smooth plates in the vault, which Prof. Williams observed in the cast of a single crushed specimen of *H. ithacensis*, I am fairly confident that there are no similar rows of plates in *H. Carpenteri*. The apparently smooth character of the plates may arise from the partial obliteration by wearing down of the tubercles, which occurs in several of my specimens, so that they can only be seen by careful observation with a lens, and the smooth plates may therefore be really due to this cause.

* *Op. cit.* p. 84.

Prof. Williams does not refer to the stem of the generic type beyond giving its thickness; but the small portion of it shown in his fig. 1, in close proximity to the body of the crinoid, resembles the stem of *H. Carpenteri* in consisting of alternating larger and smaller joints; and it is very probable that nodes with cirri were also present, as in this latter species. The other fragments figured by him as portions of the stem (figs. 7 and 8) are so entirely different in the thickness of the stem itself and of the individual joints, as also in their smooth and uniform characters, that in the absence of confirmatory evidence one cannot regard them as belonging to the same species.

Apart from the possession of articulating spines the relations of *Hystricrinus*, as already noted by Williams *, are very close to *Hexacrinus*, Austin †, a genus of crinoids which, according to Wachsmuth and Springer ‡, is almost exclusively limited to the Devonian formation in Europe, only fragments of a single species having been discovered in America. The number and arrangement of the basals, the first radials, and the anal plate are very similar in the two genera; but a comparison of the other features is rendered difficult on account of the uncertainty which prevails as to the definite characters of *Hexacrinus*. According to Zittel § this genus resembles *Platycrinus* in having a single axillary above the first radial, although rarely another intermediate so-called radial is present, and interradials are wanting. Wachsmuth and Springer ‖, on the other hand, state that there is one axillary above the first radial, that the anal plate supports two or three plates, and that the interradial series is composed of a single large plate which rests within a notch between two radials. An examination of the characters of *Hexacrinus interscapularis*, Phill. sp. ¶, the type of the genus, does not avail conclusively to solve the question, for unfortunately the number of radials above the first is not shown in Phillips's and Austin's figures; the arms and stem are wanting, but there are two zones, of two plates each, in the anal interradial area, and of three plates each in the other interbrachial or interradial areas, so that in this last feature the typical example of the genus differs from both Zittel's and Wachsmuth and Springer's

* *Op. cit.* p. 82.

† Mon. Rec. and Foss. Crinoids, 1843, p. 252.

‡ "Revision of the Palæocrinoidea," part ii., 'Proceedings of the Academy of Natural Sciences of Philadelphia,' 1881, p. 253.

§ Handb. der Pal. vol. i. p. 365.

‖ "Revision," ii. p. 253.

¶ Pal. Foss. Cornw., Geol. Surv. Mem. 1841, p. 28, pl. xiv. fig. 39.

definition. But undoubted examples of *Hexacrinus interscapularis*, in better preservation than the Devonshire specimens, have been figured by L. Schultze * from the Devonian of the Eifel; and though the arms are wanting in these, yet they distinctly show (judging from the figures) four so-called radials above the first radial, thus markedly differing not only from *Hystricrinus*, but from nearly all the other species which by Schultze and Wachsmuth and Springer are included in *Hexacrinus*.

The genus *Hystricrinus* differs from *Hexacrinus*, as exemplified by the typical species, in possessing only three radials and in having a greater number of interbrachial plates both in the anal and other interradial areas; but more particularly in the striking feature of the articulating spines and the stem with its whorls of cirri. But whilst by some authorities the differences in the somewhat inconstant characters of the number of the radials and the interbrachial plates would not be deemed sufficient to constitute a generic distinction, the presence of the articulating spines, which have hitherto not been discovered in any other genus of crinoids, either fossil † or recent, and which constitute another link of relationship between the Crinoidea and Echinoidea, might be regarded as indicating a greater than generic difference, and, provisionally at least, this genus may rank as the type of the family of the Hystricrinidæ.

I now pass on to describe in detail the specific characters of *H. Carpenteri*.

*Hystricrinus Carpenteri*, n. sp.

Body cup-shaped, widest at the summit of the first radials, then slightly contracting by the curving inwards of the interbrachial plates. The vault is flat or slightly convex. The

* Denkschr. k. k. Akad. d. Wiss. Wien, Bd. xxvi. 1867, Taf. viii. fig. 5.

† It is a noteworthy circumstance that the aberrant Blastoid, *Astrocrinites Benniei*, R. Etheridge, Jun., described and figured in the Quart. Journ. Geol. Soc. vol. xxxii. 1876, p. 103, pls. xiii., xiv., appears to have possessed articulated spines. A small spine was discovered by Mr. Etheridge adhering to one of the specimens, though not in position on the tubercle; and in a subsequent paper on this form Messrs. R. Etheridge, Jun., and P. H. Carpenter record the fact that some at least of the peculiarly ornamented tubercles, which thickly cover the surface of this species, were perforated at their summits, which renders it highly probable that they supported movable spines (Ann. & Mag. Nat. Hist. April 1883, p. 236).

Dr. Hambach, of St. Louis, also states that he possesses a specimen of *Pentremites granulatus*, Römer, on which the coarse granules show very distinct sockets for the articulation of spines (Trans. Acad. Sci. St. Louis, vol. vi. no. 3, 1884, p. 543).

height of the calyx, measuring to the distal margin of the interbrachial plates, varies from 18 to 23 millim. in different specimens, and is slightly less than their width, which varies between 20 and 25 millim.

*Basals.*—The base of the calyx has the form of an open shallow cup, the margin of which is hexagonal in figure, with indistinct angles. The lower exterior portion where it connects with the stem is circular, about 5 millim. in diameter, with a slightly projecting collar, the edges of which are finely grooved (Pl. VI. fig. 2). Within this is a slight depression and at the bottom of it a small circular aperture communicating with the interior of the calyx. The base is formed by three equal plates of a pentagonal form. The basal plates

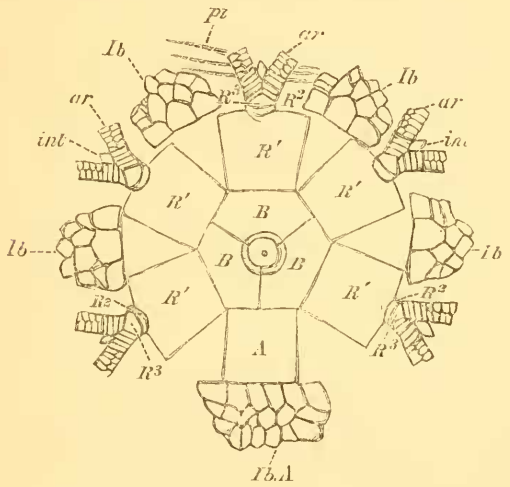


Diagram of *Hystricrinus Carpenteri*, natural size.

*A*, anal plate; *ar*, arms; *B*, basals; *Ib*, interbrachial plates; *Ib.A*, interbrachial anal plates; *int*, interaxillary plate; *pi*, pinnules; *R'*, first radial; $R^2$, second radial; $R^3$, third or axillary radial.

vary from ·3 to ·6 millim. in thickness near their upper margins, whilst near their bases they are from 1 to 2 millim. in thickness. The base itself varies from 5 to 7·5 millim. in height, and is thus about one third the entire height of the calyx; it is from 14 to 21 millim. in width. The upper margins connecting the basals with the radials are not exactly straight, but rudely crenulate, the edges slightly overlapping the radial margins.

*Radials.*—The first or true radials are relatively large flattened plates, spade-shaped or trapezoidal in form, varying from 10 to 12 millim. in height, 8 to 11 millim. in width at their bases, and between 10 and 14 millim. at their summit-margins. They are about ·75 millim. in thickness, but in the central upper portion increase to 2 millim. The basal and the two lateral margins are straight, whilst the distal is in some cases straight and in others is slightly elevated towards the centre, where there is a shallow semicircular excavation with radial ridges and grooves for the reception of the second radial. The sutural surfaces of the first radials, by which they connect with each other and the basals, are covered with very delicate transverse ridges and grooves (Pl. VI. fig. 5), whilst those of their distal margins, which connect with the interbrachial plates, run in a longitudinal direction (Pl. VI. fig. 4).

The second and third so-called radials are short thick plates or joints, whose united length varies from 2·5 to 3·25 millim., and they are about 3·5 millim. in width. The lower and shorter of the two has an oblong or trapezoidal outline, and varies in different specimens from ·8 to 1·25 millim. in height, whilst the third or axillary* radial is a small pentagonal joint 1·7 to 2 millim. in height. There are one or two spines on the dorsal surfaces of each of these upper radials. Laterally the upper radials are united by sutures to the interbrachial plates.

*Arms and Pinnules.*—The two sloping upper facets of the axillary radial each support a single arm. The first four joints of each arm are subequal, with four unequal sides, and approximately semielliptical in transverse section. They are disposed in a single vertical series, and their united length is 3·2 millim. The sutural facets of these joints are strongly grooved radially. The inner lateral faces of the first two joints of each arm are bevelled and grooved and suturally connected with the corresponding arm-joints springing from the adjoining axillary facet. The next two joints in each arm diverge from those of the corresponding arm; but they are nevertheless united together by an elongate tongue-shaped interaxillary plate. Above the fourth joint in each arm the joints become wedge-shaped and form a double alternate vertical series. The inner edges of these joints are dove-tailed into each other, so that the sutures form a zigzag line

* An abnormality occurs in one of the radial series of one of the specimens, which has two joints or plates between the first radial and the axillary, thus exhibiting four radials altogether.

on the dorsal surface of the arm. The separate joints are about ·7 millim. in height and 3·2 millim. from the dorsal to the ventral edge.

The two lowest arm-joints above the axillary radial are suturally united to the interbrachial plates, and thus bound up with the calyx; the joints above these appear to have been free, with the exception of the third and fourth, which are connected together by the interaxillary plate. There are from two to three spine-bearing tubercles on each of the arm-joints.

The pinnules consist of elongate compressed joints, horse-shoe-shaped in transverse section. The longest joint measures ·3 millim. and the terminal about 1·8 millim. They are about ·5 millim. from the dorsal to the ventral edge. In one or two cases the canals on the ventral surface can be distinguished. There are apparently six, if not more, joints in each pinnule; the facets between the joints are smooth and even. The outer surface of the joints is also smooth and free from tubercles. I am unable to determine with accuracy the lowest joint of the arms which is furnished with pinnules, but they appear to commence on the fourth or fifth above the axillary radial. In none of my specimens are there more than eight arm-joints preserved.

*Anal Plate.*—This is nearly oblong in form, very slightly wider above than below; it differs from the first radials, between two of which it is inserted, in not increasing in width to the same extent above and in the absence of the central notch and tumidity (Pl. VI. fig. 1, *A*). Its upper margin is nearly straight and in a line with that of the first radials. The plate varies from 8·5 to 10 millim. in width, and from 10 to 12 millim. in height.

*Anal Interbrachials* (Pl. VI. fig. 1, *Ib.A*).—The area covered by these plates is nearly half as large again as that in the other interbrachial spaces. In the best-preserved specimens it is 15 millim. in width at the base and at least 7·5 millim. in height. There are three vertical zones of plates exposed; the space above these is concealed from view. In the lowest zone six plates are present; the two connected with the upper radials on each side are trapezoidal in form, whilst the intermediate four plates are subequal, pentagonal, with straight bases and sides and angular summits. These plates are each about 2·5 millim. in width and from 3 to 4 millim. in height. Seven plates are present in the second series; these are polygonal, with the lower angles accurately fitting into the angles of the lower series. The upper series is also of seven plates, of a similar character to the series below them. The entire series of plates are suturally

attached together and also to the distal margins of the first radials and anal plate below, and laterally to the upper radials and the two lowest arm-joints on each side, so that they form a compact slightly incurving shield over the area. These plates are not so abundantly provided with spines as the anal and radial plates, and they are usually much smoother. There are from one to five spine-bearing tubercles irregularly disposed on each plate. The anal aperture is concealed; it is probably slightly above the third zone of plates.

*Interbrachials.*—The space covered by these plates is from 8·75 to 10·5 millim. in width in different specimens; it also varies somewhat even in the same example; the plates reach from 6 to 9·5 millim. above the distal margin of the first radials. The plates of the lower of the three zones are always three in number; they are all larger than the plates of the higher zones, and the middle of the three is very prominent. This is usually, but not invariably, situated centrally above the distal margins of the first radials; its base is generally straight, but in the rare cases in which there is an entering angle at the union of the first radials the base of this plate is angular and accurately fits into the space. Strictly, therefore, this middle plate of the lower zone is an interradial plate. This plate is from 3 to 4 millim. in width and about 4 in height. The lateral plates of the lower zone are relatively wider and shorter than the central plate; their outer margins are suturally attached to the sides of the second and axillary radials, even sometimes reaching to the lowest arm-plate. The middle zone consists of three or four polygonal plates, varying from 2 to 3 millim. in width and height, which dovetail into the open angles of the lower series, and their own summit-angles are similarly filled by the top series, usually of four plates. In one specimen there are one or two partially detached plates above the third zone; but I cannot tell whether such were generally present.

These interbrachial plates, like those of the anal area, have comparatively smooth surfaces; in some no tubercles can be detected, probably from obliteration, whilst in others there are from one to three spine-bearing tubercles. The plates are about ·5 millim. in thickness, and their sutural surfaces are furnished with longitudinal minute ridges, of which there are from four to five. In none of the specimens is the contact of the distal margins of these plates with the plates of the vault actually shown; but the vault-plates are in such close proximity (Pl. VI. fig. 10) that there can be no doubt of their original union with them.

*Vault.*—In none of my specimens is the vault complete;

but portions of it are *in situ*, and there are also numerous detached plates in the interior of an individual whose roof has collapsed. It was composed of a solid massive layer of numerous small polygonal but relatively thick plates, very intimately united together, so that the partitions between them cannot in many instances be detected *. Their contact-surfaces in some cases show minute longitudinal ridges and grooves of a similar character to those of the interbrachial plates, but finer; in other cases the contact-surfaces appear to be quite smooth. The plates throughout the vault are about ·9 millim. in thickness, and thus nearly double as thick as the interbrachial plates. Those of the peripheral area (Pl. VI. fig. 10) are not more than 1 millim. in width; their upper surfaces are now relatively smooth, but on each there are from one to four spine-bearing tubercles of two different sizes. The plates of the central portion of the vault are thickly covered with minute blunted fixed spines or tubercles, with some articulated spines as well, and also short sinuous ridges (Pl. VI. figs. 11, 12). I am unable to ascertain definitely the form and number of the plates in this central portion; some were clearly larger than those of the peripheral area, and there is a detached united mass, evidently belonging to the central area, which may be of only two or three large plates; but no divisions are perceptible in it.

*Tubercles and Spines.*—The tubercles are minute truncated cones which project slightly from the surface of the plates. Their narrow summits are perforated by a minute circular aperture or pit, from ·1 to ·15 millim. in width; their sides gradually enlarge towards the base, which varies from ·3 to ·5 millim. in width, and merges into the general surface of the plate without any distinctive collar or depression. In the best-preserved examples there is no prominent rounded knob at the summit of the tubercle. They appear to be very liable

* Prof. Williams (*op. cit.* p. 88) considers it probable that the detached spine-bearing plates described and figured under the name of *Lepidocentrus eifelianus* by Joh. Müller from the Devonian at Rommersheim, may have belonged to the vault of a crinoid similar to *Hystricrinus*. From Müller's description of these plates in the Abhandl. der königl. Akad. d. Wiss. Berlin, 1856, p. 259, it appears that their edges are bevelled and adapted to fit over each other like fish-scales. This character, and the fact that nearly similar plates have been discovered in position, forming part of the test of a *Palæchinus*, by Schultze (Denkschr. königl. Akad. d. Wiss. Wien, Bd. xxvi. 1867, p. 124, Taf. xiii. fig. 1), satisfactorily show that Müller's specimens could not have belonged to a crinoid. Their relatively large size also renders it improbable. At the same time it should be acknowledged that the simple form of the tubercles and spines and their attachment to each other in *Lepidocentrus* and also in *Pholidocidaris*, Meek and Worthen, are of the same character as in *Hystricrinus*.

to be worn down to the surface of the plate, so that in many instances they look like so many minute rings, and their real characters would scarcely be recognized in this condition.

The spines are elongate, cylindrical in section, with a slightly prominent ring or collar at their basal extremity (Pl. VI. fig. 8). The base is perforated with a minute circular pit. Just above the basal collar is a slight contraction or neck, beyond which the spine gradually increases in thickness to near its middle and then tapers to an obtuse or, in some cases, a sharp point. In some examples the spine is thickest near the base, the collar is not perceptible, and it tapers regularly to its distal end. The surface of the spines, when examined under the microscope, is seen to be ornamented with minute longitudinal parallel ridges, which do not appear to be continuously even with its surface, but at intervals project outward at a small angle; these ridges are about ·025 millim. apart. The spines vary from 1·5 to 4 millim. in length, and from ·25 to ·35 millim. in thickness. Those on the basals and first radials are tolerably uniform in size, and average 2·5 millim. in length, whilst those of the vault-plates are only 1·5 millim. in length, but nearly as thick as those of the calyx (Pl. VI. fig. 9). The spines on the arms appear to be very slender.

The excavated basal faces of the spines are approximately of the same dimensions as the summits of the tubercles, and could therefore but very slightly have overlapped or clasped these latter, and they would consequently be mainly held in position by the ligament passing between the cavity in the tubercle and that in the spine.

There is no apparent regular distribution of the tubercles and spines on the plates of the calyx. In some few cases there are rows of tubercles which seem to be parallel with the margins of the first radials; but, as a rule, the tubercles are irregularly scattered over the plates, sometimes being in close proximity or only about ·2 millim. apart, whilst not unfrequently there is an interval of 1 millim. between two of them. They are most thickly grouped on the upper tumid portion of the first radial, just below the excavated surface on which the second radial rests. There are as many as seventy-three spine-bearing tubercles on the surface of a large first-radial plate, and from fifty to sixty on smaller plates. A large basal plate has sixty-five tubercles, whilst an unusually small plate possesses only twenty-seven. The tubercles and spines of the radial and basal plates are approximately equal in size, but there are two distinct sizes of tubercles on the smaller vault-plates. The interspaces on the plates between the

tubercles appears to be smooth. It is a curious circumstance that in several instances in which the spines remain on the calyx-plate they do not lie irregularly crossed over each other, but in one nearly parallel direction, as if their attaching ligaments had simultaneously given way, and some gentle uniform influence had acted on the spines, so that they all fell in the same direction (Pl. VI. figs. 6, 7).

*Stem.*—Attached to the bases of two of my specimens (Pl. VI. figs. 1, 6) there are five or six of the upper joints of the stem, which show its characters and enable the numerous detached fragments, which are abundant in the same beds with the crinoids themselves, to be identified. I have collected thirty of these fragments, but the longest does not exceed 21 millim.

The stem is cylindrical, with a moderately large cylindrical central canal (Pl. VI. figs. 13, 14). It varies from 3 millim. in diameter in a very small form, to 6·3 millim. in a large one ; in the majority of specimens it is from 4·5 to 5 millim. in thickness, including the exterior flange. The inner canal of the stem is from 1·5 to 2·8 millim. in width (Pl. VI. fig. 15). The constituent joints or rings are of two kinds, with intermediate forms. In the larger joints the peripheral margin expands into a flange with thin edges, and the joints are nearly as thick again as the smaller intermediate joints, in which the projecting flange is either entirely absent or but very slightly developed. The larger are between ·4 and ·7 millim. in thickness, and the smaller from ·2 to ·5 millim. In some portions of the stem there are three of the smaller rings between each of the larger, which are then about 1·5 millim. apart, and the central of the smaller rings exhibits an incipient flange, whilst in others the larger are only about 1 millim. apart, with a single intervening narrow ring. The facets of the rings are even and furnished with numerous, fine, equal, radiating grooves and ridges, which extend from the exterior margin to the inner edge (Pl. VI. fig. 15). The number of these varies partly with the size of the ring. In a small ring, 3 millim. in diameter, there were sixty-four ridges, and an equal number were present in a ring 4·25 millim. in width. The face of the ring in another detached stem, 3·75 millim. in width, had seventy-five ridges, while there were only seventy-seven with a thickness of 5 millim. As a rule, these minute ridges are simple, but rarely there is a slight bifurcation or notch in them near the outer margin. There is no special delimitation of the inner margin of the stem-joints round the central canal.

At irregular intervals on the stem, whorls of cirri are

developed (Pl. VI. figs. 13, 14). The distance between the whorls varies from 5 to 14 millim., but with only the short detached fragments which I possess it is not easy to determine satisfactorily if there were regular intervals between the whorls. The whorls are unequal in size; and whilst in some the cirri, or their bases, are large and apparently full-grown, in others the cirrus-bases are very small and apparently imperfect. In several instances there is a distance of about 14 millim. between the whorls or nodes of perfectly developed cirri, and between each of these, though not centrally, there is a node of imperfectly developed cirri (Pl. VI. fig. 13). It would thus appear that in this genus whorls of cirri are developed on some of the intercalated joints between the larger nodes, which indicates a different mode of growth from that which prevails in the recent Pentacrinidæ. According to Dr. P. Herbert Carpenter* the youngest nodes are always at the top of the stem in this family, and all the joints subsequently intercalated between them are internodal.

As a rule there are five cirri in each whorl, but in some cases only four are developed; the space, however, in which the fifth should appear is vacant and marked by a slight cicatrix. Though normally the cirri of the same whorl are at the same horizontal level, yet instances occur in which one or more of the cirri are situated on joints higher or lower on the stem than those bearing the others. Similar abnormalities have been shown by Dr. P. H. Carpenter to be present in the recent Pentacrinidæ. Thus in *Pentacrinus decorus*, Wyv. Thomp.†, and in *Metacrinus cingulatus*, H. Carp. ‡, the absence of a single cirrus is not at all unfrequent; and further, in *Pentacrinus alternicirrus*, H. Carp.§, the cirri of a whorl are distributed on two nodal joints, and in a much more regular manner than appears to be the case in *Hystricrinus*.

The whorls in this genus are not, as is usually the case in the Pentacrinidæ, developed nearly entirely on the lateral surface of a single, in some respects specially modified, stem-joint; but the individual cirrus appears to commence its growth on one of the smaller joints or rings (which must have been penetrated by the cirrus-canal), and then extends above and below it, so as to cover over the space between two or three of the larger rings and the intervening smaller ones. In the whorls of the larger cirri the stem-joints are nearly entirely concealed by the cirrus-sockets, but they

* Report on the Crinoidea. Voyage of H.M.S. 'Challenger,' p. 16.
† See Report on the Crinoidea, p. 12, pl. xxxvi. fig. 1.
‡ *Id.* p. 349. § *Id.* p. 12, pl. xxv.

can be clearly distinguished beneath the smaller cirri. This extension of the cirrus-sockets over more than a single stem-joint occurs also in other Palæocrinoids, and is well shown in *Poteriocrinus rostratus*, Austin*; it is also the case in some of the recent Pentacrinidæ, as, for example, in *Metacrinus nobilis*, H. Carp.†, in which both the joint above and that below the nodal joint share in the formation of the cirrus-socket.

The nodal portion of the stem is somewhat expanded, but the increased thickness is rather owing to the cirri than to an enlargement of the stem itself. The sockets of the cirri are slightly sunk below the surface of the stem. Only the lowest four or five joints of the cirri are preserved in any of the specimens; they have a slightly oblique direction in relation to the stem, but I cannot say whether upwards or downwards. The faces of the joints are circular; they vary in diameter from 1 to 1·5 millim. in the smaller cirri, and about 2·5 millim. in the larger, and the joints are about ·4 millim. in thickness. The cirrus-joints are united to each other by radiating unequal ridges and grooves, which are proportionally larger and less numerous than those uniting the joints of the stem (Pl. VI. fig. 16). There are from twelve to fourteen ridges, which extend nearly to the centre of the face, most of which bifurcate about halfway to the margin leaving a deep groove between, and there are also short ridges between the larger. There is a minute central canal in the cirri about ·15 millim. in width, which is bordered by a slightly elevated collar.

The cirri in the same whorl are not horizontally equidistant from each other, and, at first sight, their disposition appears to be altogether irregular; but closer consideration shows, in many instances, an appearance of a bilateral arrangement. Thus frequently there are two cirri in a whorl in close proximity, whilst a considerable space separates the remaining three from this pair and from each other. Now, if a line is drawn between this pair through the stem, it bisects the base of the cirrus on the opposite side; and this cirrus, which I regard as the anterior one (Pl. VI. fig. 14), has the remaining two of the five at about equal distances on either side of it. As this disposition can be traced in several instances, it can hardly be of an accidental character. In each of the horizontal interspaces between the cirri of the larger whorls, with the exception of that between the paired cirri, there are usually two laterally compressed blunted spines, one

* Monogr. Rec. and Foss. Crinoids, pl. ix. fig. 2 *a*.
† *L. c.* p. 14, pl. xli. fig. 5.

above the other (Pl. VI. fig. 14). These spines are really portions of the thin flanges of the larger rings of the stem, and they indicate the position of the larger rings, which have been covered over by the cirrus-bases.

The points of difference between this form and *H. ithacensis*, as described by Prof. Williams, clearly indicate that it is a distinct species. The calyx is nearly twice the size, and whilst the tubercles on the corresponding plates are nearly thrice as numerous, the spines themselves, particularly those of the vault plates, are not more than one third the length of those of *H. ithacensis*. The interbrachial plates are also more numerous, and there are no indications of smooth rows of plates in the vault, as is stated to be the case in this latter species. Hitherto no cirri have been discovered in connexion with the stem of *H. ithacensis*, but it is probable such will be found to be present in this species as well.

Prof. Williams compares *H. ithacensis* with specimens of an undescribed form in the Museum of Cornell University, of which, he states, Prof. Hall has privately distributed the photograph with a name attached. As no description of these specimens has ever been published, and as I have not the opportunity, like Prof. Williams, of examining them, I cannot institute any comparison between them and *H. Carpenteri*.

An interesting feature in connexion with this species is the fact that out of eleven examples which have been discovered there are three in which a gastropod shell of the genus *Platyceras*, Conrad, is attached to the vault of the crinoid, which it nearly entirely covers. Though the shells have been somewhat displaced by the compression of the crinoids, there is clear evidence that the sinuosities of their margins, when in their original positions, very closely fitted to the surface of the crinoid vault. It is also noticeable that, in all three instances, these shells have a similar very definite position in relation to the anal aperture of the crinoid, so far as it can be determined by the situation of the anal plate; and they are so placed that the front margin of the gastropod shell would just project over this aperture. There can be no doubt that the gastropod derived its support from the materials rejected by the crinoid, whilst, at the same time, the position it had taken up does not appear to have in any way injured the crinoid; at all events, the specimens to which the shells are attached are larger and more perfect than the others.

The *Platyceras*-shells belong to two species: one, with the surface smooth, merely showing sinuous lines of growth, is closely related to *Platyceras erectum*, Hall*; whilst the other

* See Palæont. New York, vol. v. p. 5, pl. ii. figs. 4, 11.

species was provided with spines, and appears to be the small variety of *P. dumosum*, Conrad*, which is of frequent occurrence in the same beds as this crinoid.

In conclusion, I desire to express my grateful sense of the kind assistance which Dr. P. Herbert Carpenter most willingly afforded me in tracing out the relations of this crinoid, and my thanks are also due to Dr. Henry Woodward, F.R.S., for permitting me to examine the fossil crinoids in the British Natural-History Museum.

*Distribution.* Middle Devonian, Hamilton group, Arkona, Ontario, Canada.

## EXPLANATION OF PLATE VI.

*Fig.* 1. *Hystricrinus Carpenteri.* A slightly compressed specimen, showing the anal plate (*A*) with the anal interbrachial plates above it (*Ib.A*). Attached to the vault of the crinoid is a specimen of *Platyceras erectum*, Hall. Natural size.

*Fig.* 2. The base (imperfect at the margin) of a small individual, viewed from the exterior, showing the facet by which it connects with the top of the stem, and the central canal. Natural size.

*Fig.* 3. A detached first radial, with the second and axillary radials and the lower joints of the arms. Natural size.

*Fig.* 4. The sutural surface of the distal margin of part of a first radial, showing longitudinal grooves and ridges where it connects with the interbrachial plates, and radiating grooves where it unites with the second radial. Enlarged three times.

*Fig.* 5. The sutural surface of the lateral margin of two of the first radials, showing oblique ridges and grooves. Enlarged three times.

*Fig.* 6. An imperfect specimen, with its surface partially covered with spines. Natural size.

*Fig.* 7. A portion of the surface of the same specimen, enlarged three times, showing the spines, now prostrate, and the perforated tubercles to which they were articulated.

*Fig.* 8. A spine of the calyx, enlarged twelve times, showing interrupted striæ and microspines.

*Fig.* 9. A spine of one of the vault-plates, similarly enlarged.

*Fig.* 10. An imperfect individual, showing the smaller plates of the peripheral portion of the vault and some of the interbrachial plates. Enlarged twice.

*Fig.* 11. A single plate, with wrinkled ridges and grooves, from the central portion of the vault. Enlarged five times.

*Fig.* 12. Plates from the central portion of the vault, covered with short blunted tubercles and spines, similarly enlarged.

*Fig.* 13. A fragment of the stem, enlarged twice, with two whorls of mature cirri and an intermediate whorl of smaller cirri.

*Fig.* 14. Another fragment of the stem, enlarged three times, showing the socket of an anterior cirrus.

*Fig.* 15. A facet of a stem-joint, enlarged four times.

*Fig.* 16. A facet of a cirrus-joint, similarly enlarged.

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* Third Annual Report, New York Survey, Pal. Dept. 1840, p. 205.